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(54) **LEVEL DETECTOR FOR MEASURING FOAM AND AERATED SLURRY LEVEL IN A WET FLUE GAS DESULFURIZATION ABSORBER TOWER**

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G01F 23/00 (2006.01)

(52) **U.S. Cl.**
USPC .... **73/290 R**

(58) **Field of Classification Search**
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See application file for complete search history.

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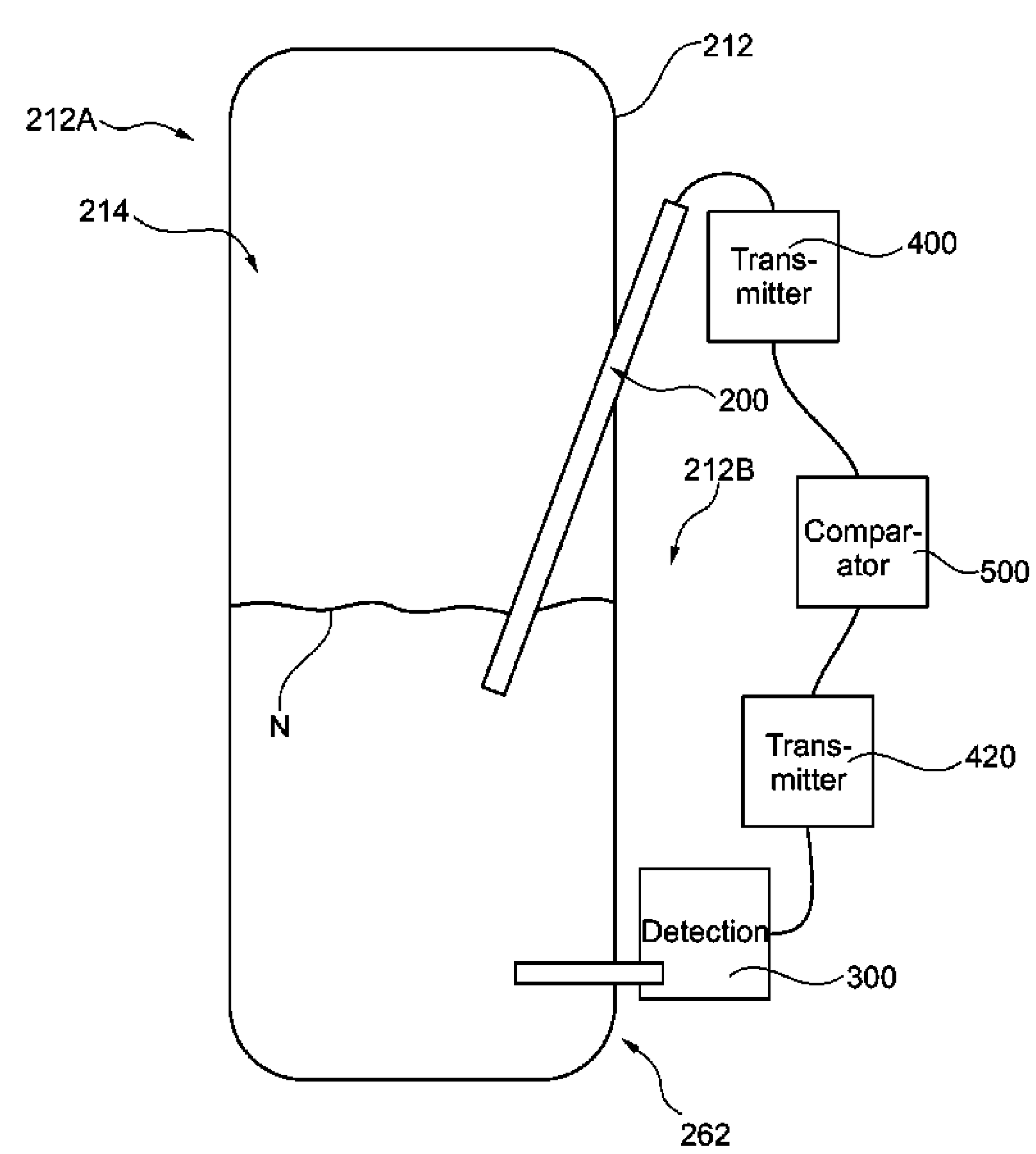
(57) **ABSTRACT**

A level detector **100** includes a sleeve **210** mountable to a vessel and extendable through a wall **212** defined by the vessel **212**A and into an interior area **214** defined by the vessel. The sleeve **210** is mountable at an angle A of less than forty-five degrees relative to the vessel wall **212**. The level detector **100** includes a level sensing probe **230** extending into a bore defined by an inside surface **218** of the sleeve **210**. The level sensing probe **230** is configured to measure a plurality of foam and aerated slurry levels in the vessel **212**A. One or more connectors **232**, **244** are positioned outside **212**B of the vessel **212**A to removably support the level sensing probe **230** within the bore. The level sensing probe **230** is in communication with the interior area **214** via one or more openings **254**, **258** extending into the bore.

19 Claims, 7 Drawing Sheets



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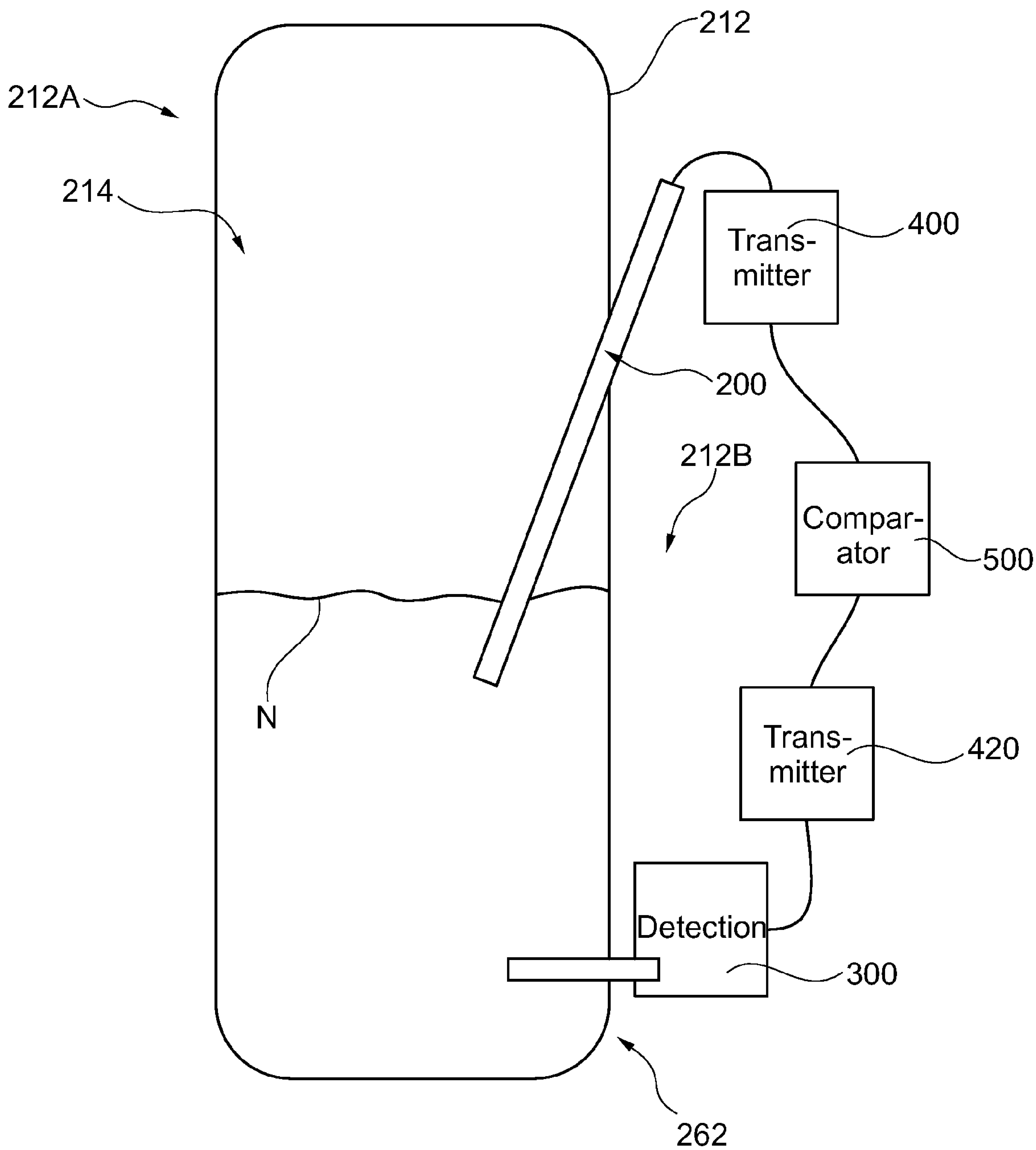

212
212A
214
Trans-
mitter
400
200
212B
Compar-
ator
500
N
Trans-
mitter
420
Detection
300
262

Fig. 1

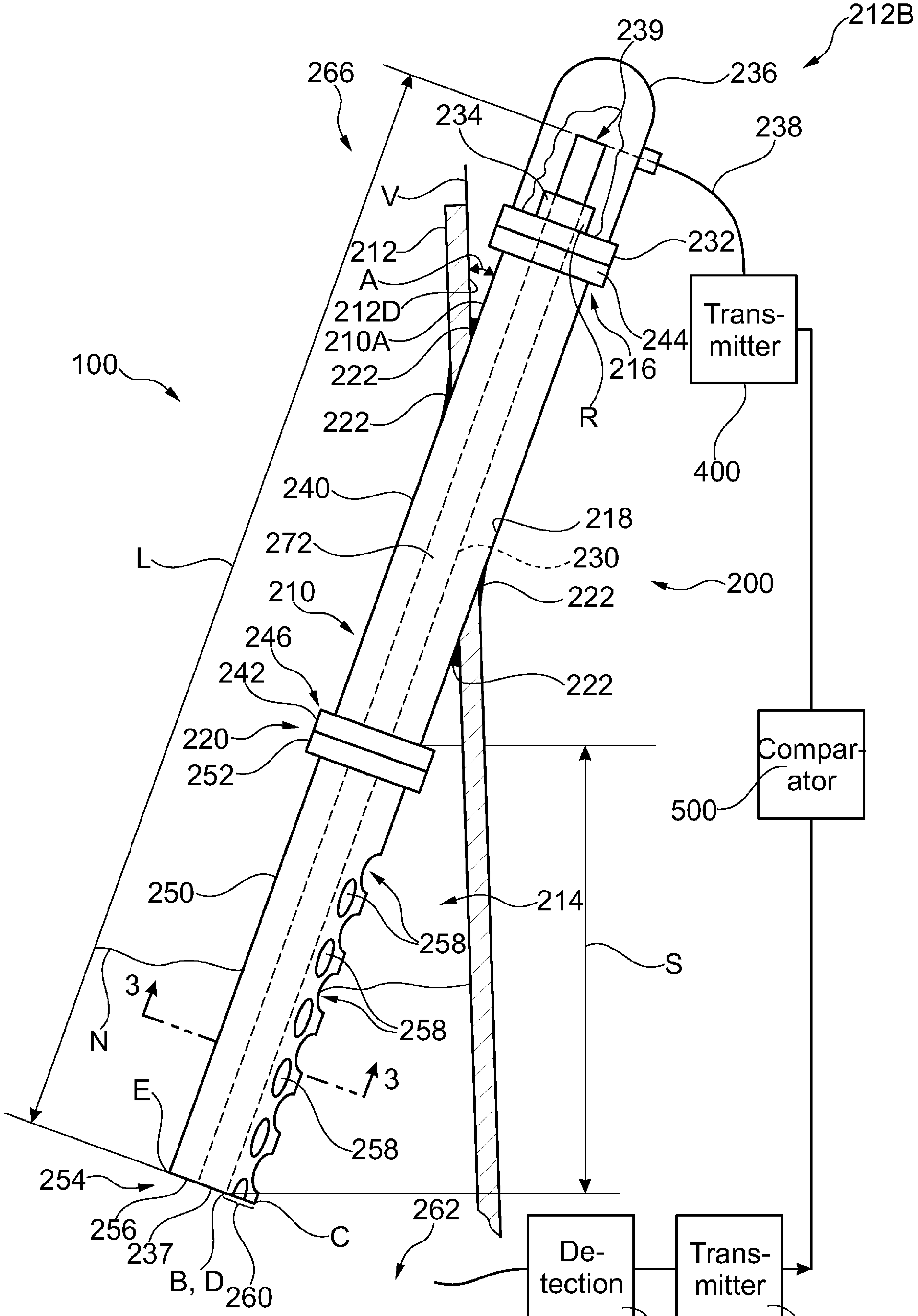
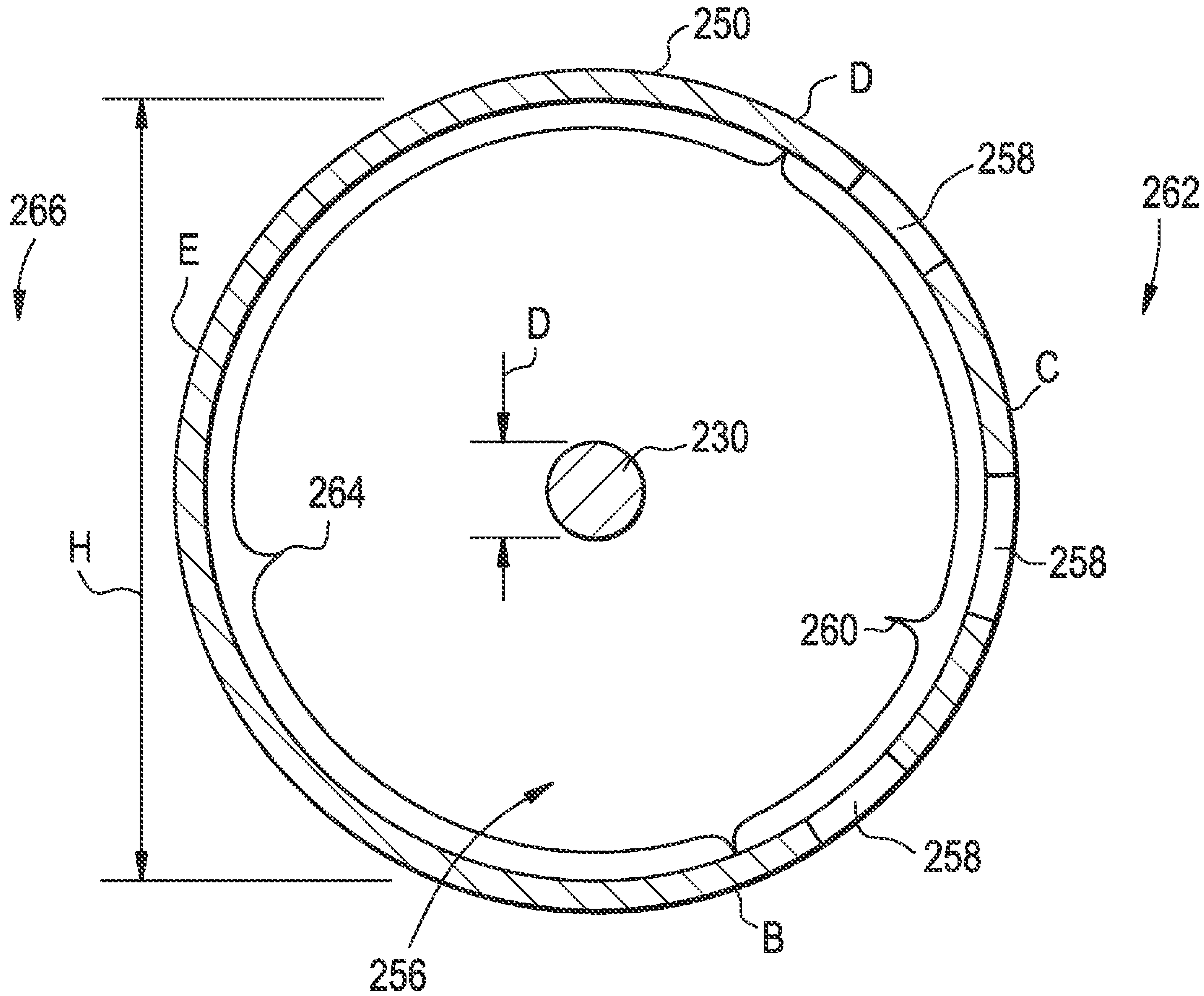

212B
239
236
266
234
238
V
232
212
A
212D
210A
Trans-
mitter
244
216
222
222
R
100
400
240
218
272
230
L
222
200
210
246
222
242
220
Compar-
ator
252
500
250
214
258
S
258
3
N
3
258
E
254
256
237
B, D
260
C
262
De-
tection
Trans-
mitter
300
420

Fig. 2

FIG. 3



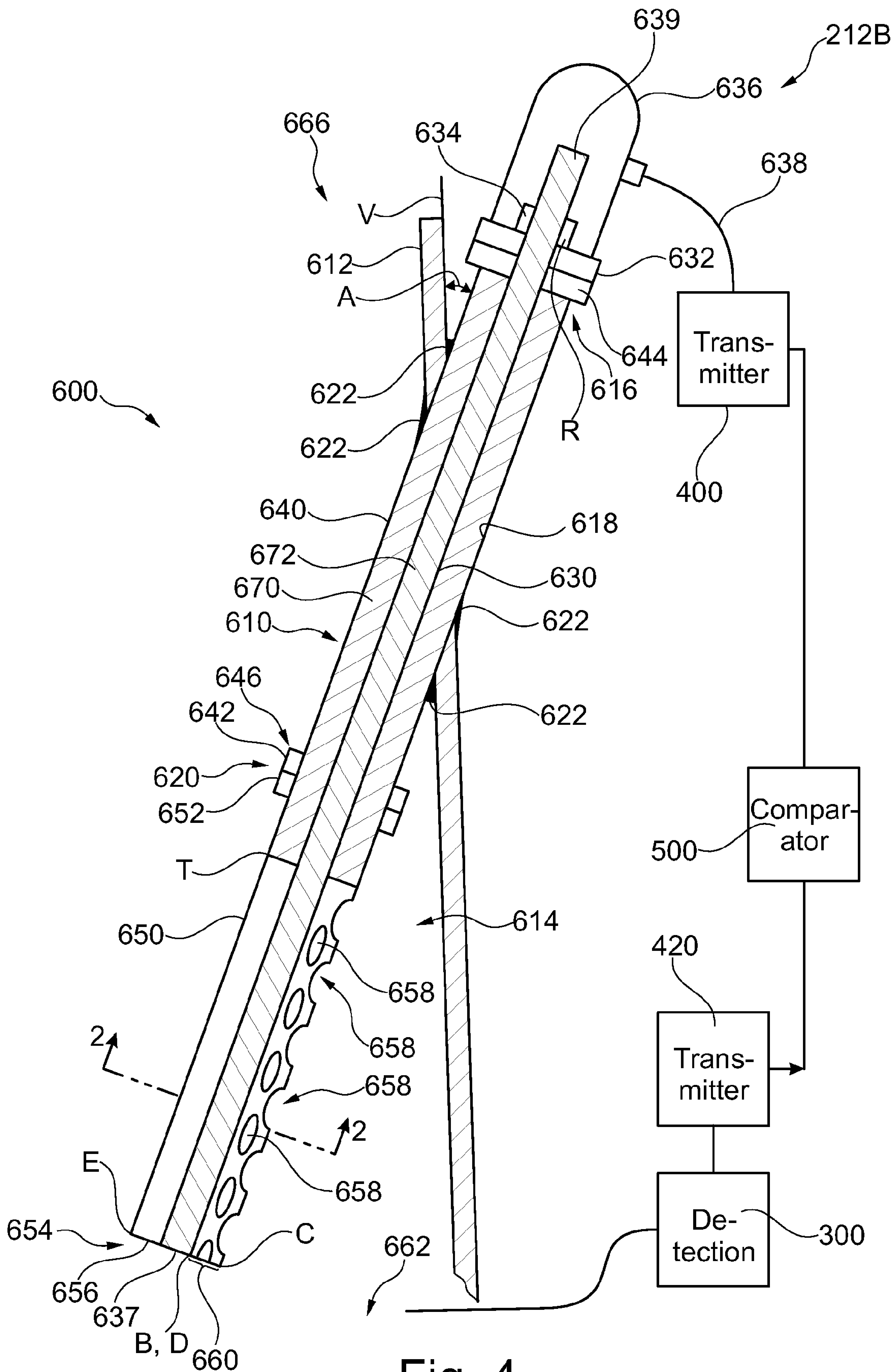

639
212B
636
666
634
638
V
612
632
A
Trans-
mitter
644
622
616
600
622
R
400
640
618
672
630
670
622
610
646
642
622
620
652
Compar-
ator
500
T
614
650
420
658
658
2
Trans-
mitter
658
2
E
658
654
De-
tection
300
C
662
656
637
B, D
660

Fig. 4

FIG. 5

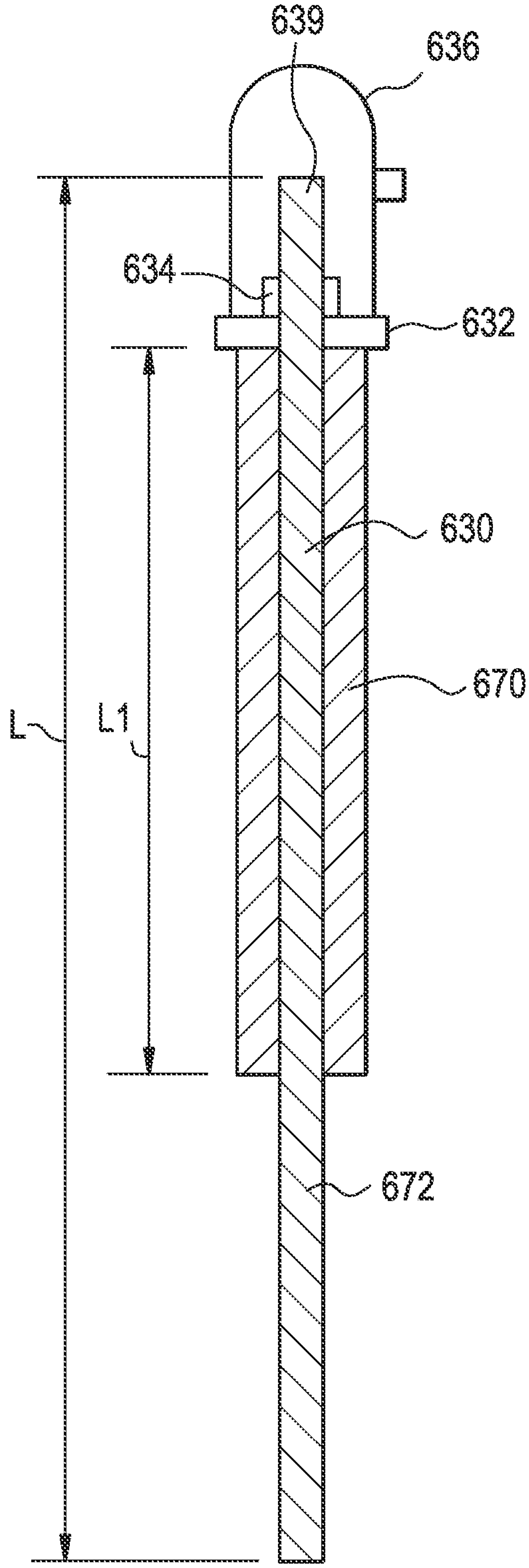


FIG. 6

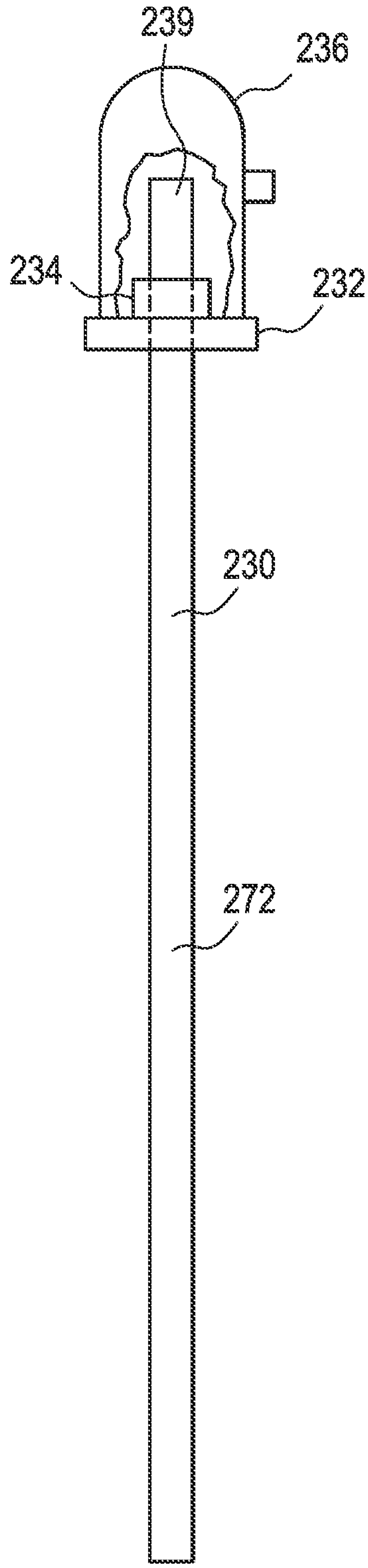
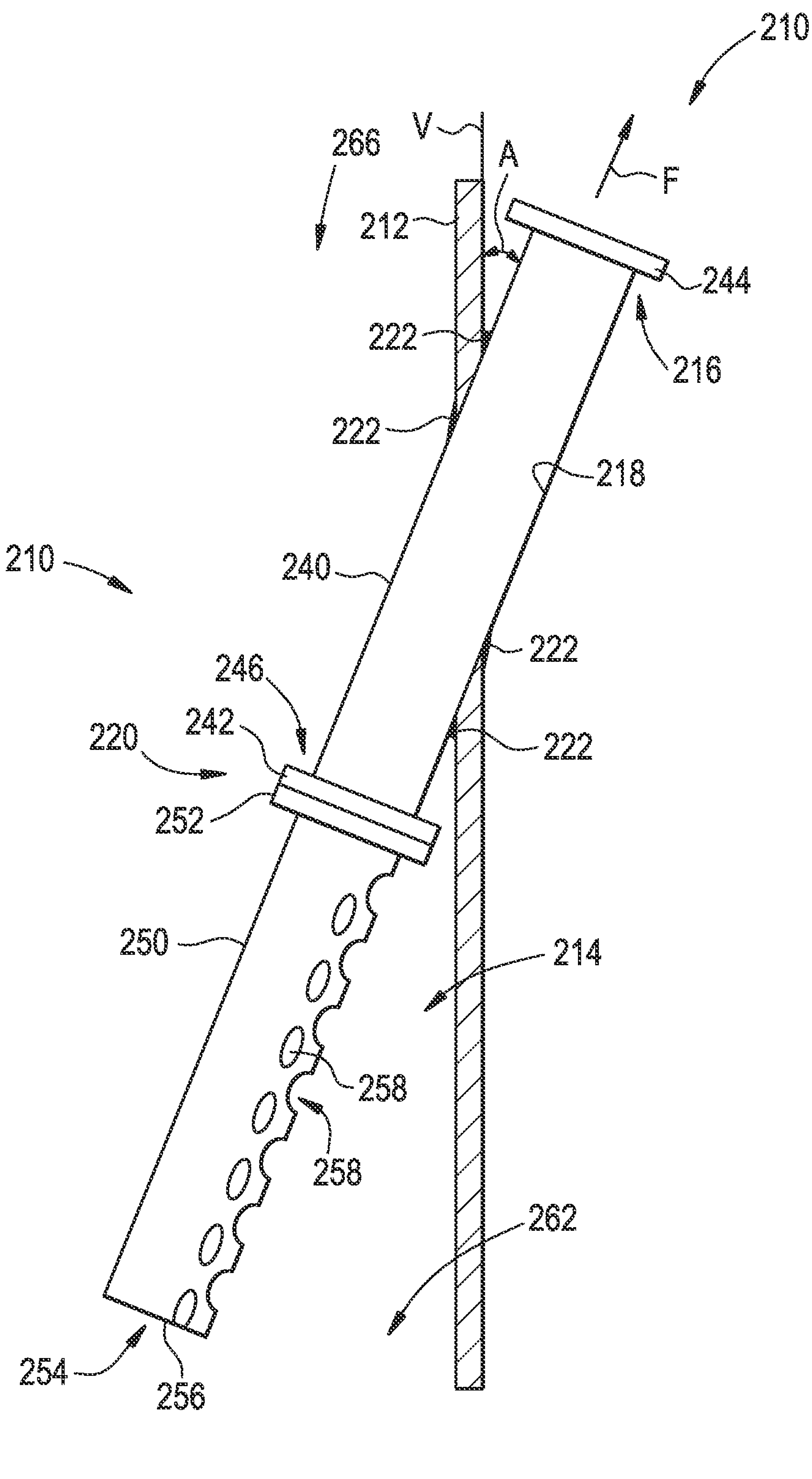


FIG. 7


210
V
266
A
F
212
244
222
216
222
218
210
240
222
246
220
242
222
252
250
214
258
258
262
254
256

LEVEL DETECTOR FOR MEASURING FOAM AND AERATED SLURRY LEVEL IN A WET FLUE GAS DESULFURIZATION ABSORBER TOWER

FIELD OF THE INVENTION

The present invention is generally directed to a level detector and is more specifically directed to a level sensor assembly for detecting foam and aerated slurry level, in conjunction with a liquid level detector in a wet flue gas desulfurization absorber tower. The detector will measure foam and/or aerated slurry level.

BACKGROUND OF THE INVENTION

Some fossil fueled power plants combust coal for the production of steam and electricity. Coal contains sulfur. As a result of the combustion of the coal, a portion of the sulfur reacts with oxygen and forms sulfur dioxide (SO_2), which is present in flue gas generated by the combustion. Sulfur dioxide is a known pollutant. Accordingly, several countries have established environmental regulations to limit the amount of sulfur dioxide in flue gas. One method of reducing or eliminating sulfur dioxide in flue gas is to treat the flue gas in a desulfurization absorber tower. The flue gas can react with a slurry of wet limestone ($CaCO_3$) in the absorber tower to form calcium sulfite ($CaSO_3$) and calcium sulfate ($CaSO_4$).

The absorber towers are typically 50-60 foot diameter pressure vessels accommodating limestone/gypsum slurry levels of 40 feet or more. The absorber towers generally define an inlet duct for introducing the flue gas into the absorber tower and an outlet duct for discharging treated gases. In some instances, an induced draft fan is positioned just ahead of the absorber tower in the inlet duct. Automatic controls are used to maintain predetermined slurry levels in the absorber tower.

Chemical reactions between the flue gas, the slurry and other chemicals in the absorber tower and air, which is injected into the slurry at the bottom of the absorber tower, can produce foam and aerated slurry floating on the slurry. If undetected, the foam and/or aerated slurry can accumulate and overflow into the inlet duct and damage the induced draft fan.

SUMMARY OF THE INVENTION

According to aspects disclosed herein, there is provided a level detector, which includes a sleeve mountable through a wall defined by a vessel and into an interior area of the vessel. The sleeve is mountable at an angle of less than forty-five degrees relative to the vessel wall. The level detector includes a level sensing probe extending into a bore defined by the sleeve. The level sensing probe is configured to measure a plurality of foam and/or aerated slurry levels in the vessel. One or more connectors are positioned outside of the vessel to removably support the level sensing probe within the bore. The level sensing probe is in communication with the interior area via one or more openings extending into the bore.

In one embodiment, one or more of the connectors (e.g., a flanged connector or a threaded coupling) and the level sensing probe are operable to enable the level sensing probe to be installed and removed from the sleeve from a position external to the vessel without requiring access to the interior area.

In one embodiment, the level sensing probe defines a stiffness such that the probe is maintained in a position spaced away from an inside surface of the sleeve. In addition, a spacer can be positioned in the sleeve between the level sensing probe and the inside wall of the sleeve.

The level detector can include a liquid level sensor and a comparator module (e.g., a programmable logic controller). In one embodiment, the comparator module is in communication with the liquid level sensor and the level sensing probe. In addition, the comparator module includes an algorithm which generates a foam and aerated slurry level measurement by subtracting a liquid level measurement generated by the liquid level sensor, from the level measurement generated by the level sensing probe.

The level sensing probe can be a radio frequency (RF) admittance probe, a guided wave radar probe or other probe such as those that can be installed in a configuration spaced apart from the sleeve.

A method for measuring foam and aerated slurry in a vessel is also disclosed herein. The method includes providing a sleeve mountable to the vessel and extendable through a wall defined by the vessel into an interior area of the vessel. The sleeve is mountable at an angle of less than forty-five degrees relative the vessel wall. A level sensing probe is provided which is installable into a bore defined by an inside surface of the sleeve. A liquid level sensor is also provided which is mountable to the vessel and extendable through the wall into the interior area of the vessel. A comparator module in communication with the liquid level sensor and the level sensing probe is also provided. The comparator module generates a foam and aerated slurry level measurement by subtracting a liquid level measurement generated by the liquid level sensor, from another level measurement generated by the level sensing probe.

DESCRIPTION OF THE DRAWINGS

Referring now to the Figures, which are exemplary embodiments, and wherein the like elements are numbered alike:

FIG. **1** is a schematic side cross sectional view of a vessel having a foam detection assembly installed therein;

FIG. **2** is a side cross sectional view of a vessel section having a foam detection assembly of FIG. **1** installed therein;

FIG. **3** is a top cross sectional view of a portion of the foam detection assembly of FIG. **2** taken along line **3-3**;

FIG. **4** is a side cross sectional view of a vessel section having another embodiment of the foam detection assembly of FIG. **2**;

FIG. **5** is a side cross sectional view of the level sensing probe of FIG. **4**, shown removed from the foam detection assembly;

FIG. **6** is a side view of a level sensor of FIG. **2**, shown removed from the foam detection assembly; and

FIG. **7** is a side view of a sleeve for the foam detection assembly of FIG. **2** shown with the level sensor removed from the foam detection assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Disclosed herein is a level detector for measuring the level of foam in a vessel, for example, in an absorber tower of a wet flue gas desulfurization system. Referring to FIGS. **1** and **2**, the level detector is generally designated by the numeral **100**. The level detector **100** includes a foam/aerated slurry detection assembly **200** in communication with a first transmitter **400** and a liquid detection assembly **300** in communication with a second transmitter **420**. The first **400** and second **420** transmitters are in communication with a comparator module

500, for example a programmable logic controller, a computer program and/or a controller, for comparing and calculating vessel foam and aerated slurry level, as described in more detail below. The foam/aerated slurry detection assembly **200** measures a combined level of foam, aerated slurry and liquid level in the vessel **212**A. The liquid detection assembly **300** is positioned in a portion of the vessel **212**A, below a normal liquid level N (e.g., a bottom **262** portion of the vessel) and can include, for example, a differential pressure sensor or other suitable sensor that measures liquid level. The comparator module **500** includes an algorithm operable to subtract liquid level from the combined level (i.e., of foam, aerated slurry and liquid level) to arrive at the foam and aerated slurry level in the vessel **212**A. The comparator module **500** is in communication with a display and a control module. A screen portion of the display exhibits indicia representative of the level of foam in the vessel **212**A, such as in the form of a numerical value, chart, graph or the like, which communicates the level of foam and aerated slurry in the vessel **212**A. The control module receives combined foam and aerated slurry level signals from the comparator module **500** and transforms the combined foam and aerated slurry level signals into control signals for controlling equipment, such as anti-foaming agents and level control valves in the wet flue gas desulfurization system.

As illustrated in FIGS. **1** and **2**, the foam/aerated slurry detection assembly **200** includes a sleeve **210**, for example a pipe, extending through a wall **212** (e.g., a vertical wall) of a vessel **212**A and into an interior area **214** of the vessel **212**A. The sleeve **210** is mountable with its uppermost surface **210**A at an angle A of about fifteen degrees relative to a reference line V, i.e., the exterior surface **212**D of wall **212**. The foam/aerated slurry detection assembly **200** includes a level sensing probe **230**, such as but not limited to a radio frequency (RF) admittance probe and a guided wave radar probe, removably secured to an end **216** of the sleeve **210**, located external **212**B to the vessel **212**A. A distal end **256** of the sleeve **210** defines an opening **254** so that the level sensing probe **230** can communicate with the interior area **214**, as described below. In one embodiment, the sleeve **210** and the level sensing probe **230** extend from the wall **212** in a generally downward direction towards a bottom **262** of the vessel **212**A. While the level sensing probe **230** is described as being a RF admittance probe or a guided wave radar probe, other level sensing probes may be employed including but not limited to those that can be installed in a configuration spaced apart from the sleeve **210**.

A first connector **232**, such as but not limited to a flanged joint, a threaded coupling and a bayonet fitting, is secured to the level sensing probe **230** by a locking member **234** (e.g., a threaded coupling or a compression fitting). The first connector **232** is removably secured to the sleeve **210** by a second connector **244** (e.g., a flanged joint, a threaded coupling or a bayonet fitting) mounted on the sleeve **210**. The first and second connectors **232** and **244**, respectively, are located outside **212**B the vessel **212**A and cooperate with one another to position the level sensing probe **230** inside a bore defined by an inside wall **218** of the sleeve **210**. The level sensing probe **230** defines a stiffness such that the level sensing probe is maintained spaced away from the inside wall **218**, for example, positioned substantially concentric within the sleeve **210**. Thus the level sensing probe **230** is mountable and operable at an angle of about fifteen degrees from the reference line V, e.g., the vertical wall **212**. The level sensing probe **230** is supported in a cantilever configuration, from the locking member **234** at point R to a free end **237** of the level sensing probe **230**, by the first and second connectors **232** and **244**. Thus portions of the level sensing probe **230** disposed within interior area **214** of the vessel **212**A have no support members secured thereto. Another end **239** of the level sensing probe **230** is contained within a housing **236** and is in communication with the first transmitter **400** via a suitable transmission device **238** (e.g., wiring and/or wireless transmission) The first transmitter **400** is in communication with the comparator module **500**. While the sleeve **210** and level sensing probe **230** is shown and described as being mountable at an angle A of fifteen degrees relative to the reference line V, other angles may also be employed, for example sleeves **210** being mountable at an angle less that 45 degrees or at an angle between about 14 and 16 degrees, relative to the reference line V, can also be employed without departing from the broader aspects disclosed herein.

Mounting the sleeve **210** and the level sensing probe **230** at an angle of about 15 degrees, 14 to 16 degrees or less than 45 degrees from the reference line V, e.g., the vessel **212**A wall **212** places the probe **230** away from a central portion of the vessel **212**A where the slurry may be traveling at a higher velocity than the velocity in an area adjacent to the wall. Slurry traveling at such a high velocity could lead to probe **230** damage resulting in erroneous level measurements. In addition, as the angle A is increased beyond 45 degrees, the level sensing probe **230** tends to bend and become non-concentric within the sleeve **210**, thereby causing inaccurate level measurements.

As illustrated in FIG. **2**, the sleeve **210** includes a mounting portion **240** and a measuring portion **250**, removably secured to one another by a connector **220**, for example, a pair of flanges **242** and **252**, a threaded coupling or a bayonet fitting. The mounting portion **240** is mountable to the wall **212**, for example by a welded joint **222**. An end **246** of the mounting portion **240** and the measuring portion **250** are positioned in the interior area **214** of the vessel **212**A and are also positioned at an angle A of about fifteen, 14 to 16 degrees or less than 45 degrees from reference line V, e.g., the vertical wall **212**. The mounting portion **240** is manufactured from a metal or alloy comparable to that of the vessel **212**A.

The measuring portion **250** is manufactured from a material that can withstand corrosive attributes of the slurry, aerated slurry and foam. In one embodiment, the measuring portion **250** is a piece of pipe such as, but not limited to fiberglass reinforced pipe, plastic pipe or stainless steel pipe. Plastic and fiber reinforced pipe can be used to reduce costs and simplify manufacturing and assembly. The measuring portion **250** has an opening **254** at the distal end **256** thereof. The measuring portion **250** also includes a plurality of passages **258** extending therethrough. As illustrated in FIGS. **2** and **3**, the passages **258** are positioned on a first section **260** of the measuring portion **250** toward the bottom **262** of the vessel **212**A, for example in section BCD which defines an arc of less than 180 degrees through points B, C and D. The opening **254** and the passages **258** allow slurry, aerated slurry and foam to enter the measuring portion **250** and to communicate with the level sensing probe **230**. A second section **264** of the measuring portion **250** toward top **266** of the vessel **212**A, for example, section BED, is substantially solid and has no passages extending therethrough. Therefore, the second section **264** protects the level sensing probe **230** from being impinged by downwardly falling slurry circulating in the vessel **212**A.

In one embodiment, the level sensing probe **230** includes a probe rod **272**, for example a solid cylindrical shaft manufactured of a material compatible with the slurry, aerated slurry and foam, such as, but not limited to carbon steel. In one embodiment, the probe rod **272** has an outside diameter D of about 0.84 inches, including a corrosion resistant coating or insulating material, which can be disposed thereon. The coating or insulating material also minimizes build up of slurry, aerated slurry and foam on the probe rod **272**. The probe rod **272** is about 7 to 20 feet in length L. In one embodiment, the probe rod **272** is coated with a corrosion resistant insulating material such as, but not limited to a thermoplastic fluoropolymer resin (e.g., Kynar®), polyvinylidene fluoride (PVDF) and/or polytetrafluoroethylene (PTFE). In one embodiment, the sleeve **210** has an inside diameter of about 3.5 to about 4.5 inches. While the probe rod **272** is described as being a coated solid cylindrical shaft of about 0.84 inches in diameter and 7 to 20 feet in length, other sizes and cross sectional shapes may be employed, including but not limited to rectangular, triangular and/or oval cross sections and rods of any diameter and length.

The foam/aerated slurry detection assembly of FIGS. **4** and **5** is similar to the foam/aerated slurry detection assembly **200** illustrated in FIGS. **1**, **2** and **3**. Accordingly, like elements have been assigned like element numbers with the first digit **2** being replaced by the number **6**. The level sensing probe **630** includes an annular spacer **670** operable to support the level sensing probe **630**. The spacer **670** extends through substantially all of the mounting portion **640** and into a portion of the measuring portion **650**. In one embodiment, the spacer **670** extends to a point T about 4 inches into the measuring portion, measured from the flange **652**. The spacer **670** can be manufactured from a material such as, but not limited to a synthetic fluoropolymer of tetrafluoroethylene or polytetrafluoroethylene (PTFE) (e.g., Teflon®) and is secured to the level sensing probe **630**. The spacer **670** minimizes build up of slurry in the mounting portion **640**. The level sensing probe **630** is supported in a cantilever configuration, from the point T to a free end **637** of the level sensing probe **630**, by the first and second connectors **632** and **644**, the mounting portion **640**, a portion of the measuring portion **650** and the spacer **670**. Thus portions of the level sensing probe **630** from the point T to the free end **637** have no support members secured thereto.

As illustrated in FIGS. **6** and **7**, the level sensing probe **230** can be removed from the sleeve **210** by disengaging the first and second connectors **232** and **244**, respectively, from one another and withdrawing the level sensing probe **230** in the general direction indicated by the arrow F. Thus the level sensing probe **230** can be installed and removed from the sleeve **210** from a position external **212**B to the vessel **212**A and without requiring access to the interior area **214**.

During operation, the foam/aerated slurry detection assembly **200** measures a plurality of foam, aerated slurry and/or slurry levels in the vessel **212**A of the wet flue gas desulfurization system at temperatures of about 135° F. to about 145° F. The foam/aerated slurry detection assembly **200** has a level detection range S, for example, a level detection range S of about 4 to 6 feet. The level sensing probe **230** is positioned in the vessel **212**A such that a normal slurry level N is within the detection range S. In one embodiment, the level sensing probe **230** is an RF admittance probe which employs radio frequency waves and measures capacitance and resistance of a dielectric material, such as the foam and the slurry, located between the probe and the wall **212** of the vessel **212**A. In one embodiment, the level sensing probe **230** is a guided wave radar probe. The level sensing probe **230** includes suitable electronics to generate a first level signal for transmission to the comparator module **500**. In addition, the liquid detection assembly **300** generates a liquid level signal for transmission to the second transmitter and subsequently to the comparator module **500**. The comparator module **500** includes an algorithm that is configured to subtract the liquid level signal from the first level signal to arrive at the foam and aerated slurry level measurement. The foam and aerated slurry level can be shown on the display and/or used by the control module for controlling equipment, such as anti-foaming agents and level control valve in the wet flue gas desulfurization system.

A method for measuring foam and aerated slurry in a vessel is also disclosed herein. The method includes providing a sleeve mountable to the vessel and extendable through a wall defined by the vessel into an interior area of the vessel. The sleeve is mountable at an angle of less than forty-five degrees relative the vessel wall. A level sensing probe is provided which is installable into a bore defined by an inside surface of the sleeve. A liquid level sensor is also provided which is mountable to the vessel and extendable through the wall into the interior area of the vessel. A comparator module in communication with the liquid level sensor and the level sensing probe is also provided. The comparator module generates a foam and aerated slurry level measurement by subtracting a liquid level measurement generated by the liquid level sensor, from another level measurement generated by the level sensing probe.

While the present disclosure has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A foam and aerated slurry level detector comprising:

a sleeve mountable to a vessel and extendable through a wall defined by the vessel into an interior area defined by the vessel, the sleeve being mountable at an angle of less than forty-five degrees relative to the wall defined by the vessel;

a level sensing probe configured to measure a plurality of foam and aerated slurry levels in the vessel, to extend into a bore defined by an inside surface of the sleeve, and to communicate with the interior area via at least one opening in the sleeve which extends into the bore;

at least one connector positioned outside of the vessel and configured to removably support the level sensing probe within the bore;

a liquid level sensor mounted to the vessel and extended through the wall into the interior area of the vessel to measure liquid level; and

a comparator module in communication with the liquid level sensor and the level sensing probe to determine a foam and aerated slurry level by subtracting a liquid level measured generated by the liquid level sensor, from another level measurement generated by the level sensing probe.

2. The level detector of claim **1**, wherein the at least one connector and the level sensing probe are operable to enable the level sensing probe to be installed and removed from the sleeve from a position external to the vessel without requiring access to the interior area.

3. The level detector of claim **1**, wherein the level sensing probe defines a stiffness such that the level sensing probe is spaced away from the inside surface of the sleeve.

4. The level detector of claim 1, wherein the level sensing probe is configured to operate in a wet flue gas desulfurization absorber tower at a temperature of about 135 to about 145 degrees Fahrenheit.

5. The level detector of claim 1, wherein the level sensing probe is about 7 to 20 feet in length.

6. The level detector of claim 1, wherein the level sensing probe includes a corrosion resistant coating disposed thereon.

7. The level detector of claim 1, wherein the level sensing probe is a radio frequency admittance probe.

8. The level detector of claim 7, wherein the radio frequency admittance probe is configured to employ a radio frequency signal and is configured to measure capacitance and resistance of material disposed between the radio frequency admittance probe and the wall.

9. The level detector of claim 1, wherein the at least one connector comprises a first flange secured to the sleeve and a second flange secured to the level sensing probe and wherein the first and second flanges are removably connected to one another.

10. The level detector of claim 1, wherein the sleeve is mountable at an angle of about 14 degrees to about 16 degrees, relative to the vessel wall.

11. The level detector of claim 1, wherein the level sensing probe is mountable and operable at an angle of about 14 degrees to about 16 degrees, relative to vessel wall.

12. The level detector of claim 1, wherein the sleeve and the level sensing probe extend from the wall towards a bottom portion of the vessel.

13. The level detector of claim 1, wherein the sleeve comprises a mounting portion secured to the wall and a measuring portion removably connected to the mounting portion inside the vessel, the mounting portion being a metallic material and the measuring portion being configured to allow slurry, aerated slurry and foam to come into contact with the level sensing probe.

14. The level detector of claim 13, wherein the measuring portion is manufactured from plastic or other non-metallic material.

15. The level detector of claim 13, wherein the measuring portion includes a plurality of passages extending therethrough.

16. The level detector of claim 1, wherein the comparator module includes an algorithm configured to generate a foam and aerated slurry level measurement by subtracting a liquid level measurement generated by the liquid level sensor, from another level measurement generated by the level sensing probe.

17. The level detector of claim 1, wherein the level sensing probe is spaced away from the inside surface of the sleeve and is positioned substantially concentric within the bore.

18. The level detector of claim 1, wherein the level sensing probe is a guided wave radar probe.

19. A method for detecting foam and aerated slurry in a vessel comprising:

using a level sensing probe installed into a bore defined by an inside surface of a sleeve mounted to a vessel to extend through a wall defined by the vessel into an interior area of the vessel with the sleeve mounted at an angle of less than forty-five degrees relative to the wall defined by the vessel, to measure liquid, foam and aerated slurry level;

using a liquid level sensor mounted to the vessel and extended through the wall into the interior area of the vessel, to measure liquid level; and

using a comparator module in communication with the liquid level sensor and the level sensing probe to determine a foam and aerated slurry level by subtracting a liquid level measurement generated by the liquid level sensor, from another level measurement generated by the level sensing probe.

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